Development of a Protocol for Monitoring Status and Trends in Forest Soil Carbon at a National Level

FOREST HEALTH MONITORING

Soils Indicator

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ABSTRACT

The national Forest Health Monitoring (FHM) program requires protocols for monitoring soil carbon contents. In a pilot study, thirty FHM plots loblolly/shortleaf forests across Georgia were sampled by horizon and by depth increments. For total soil carbon, approximately 70% of the variance was between plots, 25% between subplots and 5% within subplots. Results by depth differed from those obtained by horizon primarily due to the rapid changes in carbon content from the top to the bottom of the A horizon. Published soil survey information overestimated bulk densities for these forest sites. The measurement of forest floor depths as a substitute to sampling did not provide reliable estimates of forest floor carbon. Precision of replicate samples was approximately 10 -30% for field duplicates and 5 -10% for laboratory duplicates. Based on national indicator evaluation criteria, sampling by depth using bulk density core samplers has been recommended for national implementation. Additional procedures are needed when sampling organic soils or soils with a high percentage of large rock fragments.

INTRODUCTION

Soil organic matter (SOM) is an important constituent of forest soils. SOM interacts with other soil components influencing soil chemical, physical and biological properties. Specific soil properties affected by SOM include soil pH, buffer capacity, cation exchange capacity, sorption of pesticides, water infiltration, water retention, aeration, color, and the activity of soil organisms. SOM is a major source of nutrients to plants, particularly nitrogen and phosphorus. Forest litter and organic materials are critical to the protection of mineral soil from erosion. Soil structural characteristics are also affected by SOM including their form, stability and resiliency and bulk density.

Large amounts of the total carbon reserves in forests (~50%) are located in SOM in the forest floor and mineral soil. The reforestation of former agricultural lands has resulted in a significant accumulation of soil carbon. Increasing the sequestration of carbon in the terrestrial biosphere may be an inexpensive way to help mitigate the increasing concentration of atmospheric carbon while providing ancillary benefits such as improved soil productivity. However, this approach can only be implemented if accounting rules have been determined. International agreements such as the Kyoto Protocol will require agreed-upon monitoring and verification procedures of carbon sequestration in soil.

Forest management operations such as cultivation, prescribed burning, harvesting, ground preparation, thinning and drainage can affect SOM content. Forest soils with thin litter layers or high rock contents are particularly sensitive to management disturbances that can change SOM levels. As temperatures rise and season lengths increase in the high latitudes, the rate of decomposition of SOM will also increase, possibly leading to a decrease in forest soil carbon levels. Land managers are therefore interested in monitoring the effects of land management practices and climate change on SOM levels.

Given the importance of SOM to forest productivity, the role of SOM in the global carbon cycle, and the potential to affect SOM levels through land management practices, it is not surprising to see a growing interest in the development of national monitoring protocols for the measurement of soil organic carbon..

To measure changes in SOM, a sample of the soil must be taken for analysis of total carbon in the laboratory. In addition, the bulk density of the soil in the field must be measured. During the summer of 1999, several bulk density procedures were field tested. the only procedure deemed as logistically feasible for FHM field crews was sampling with a small 5 cm diameter cylinder using commercially available equipment

OBJECTIVE

The objective of this poster is to present the results of a special study conducted in the fall of 1999 to assess this proposed soil monitoring protocol.

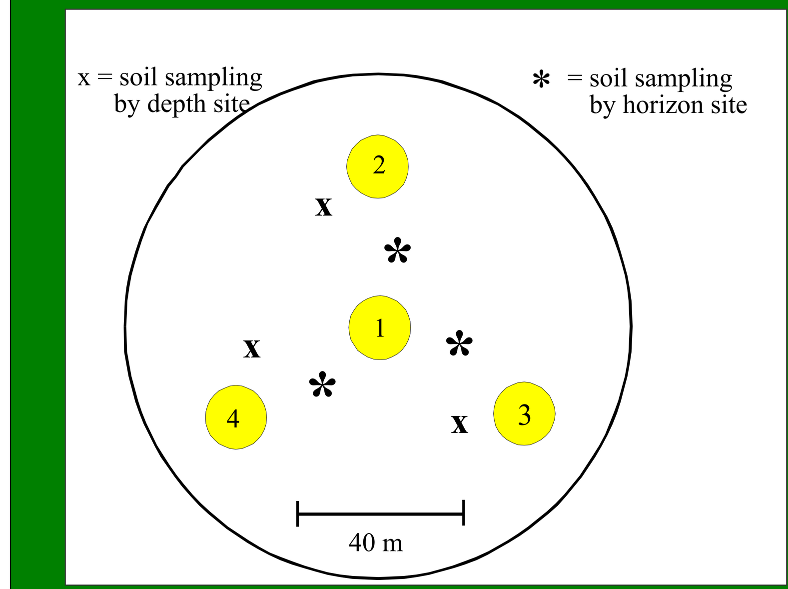

Figure 1. Location of sampling sites

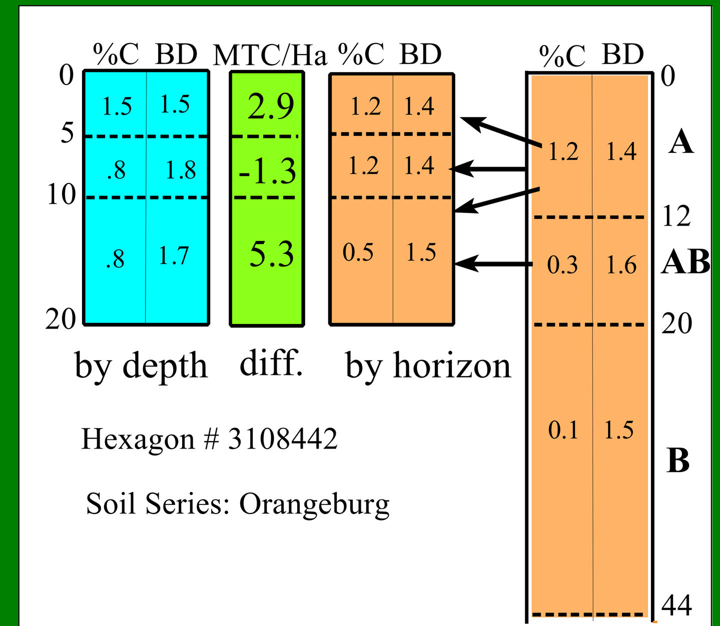

Figure 2. Comparison of soil carbon estimates using two approaches to soil sampling

Table 1. Components of variance for bulk density, percent carbon and total carbon.

Depth	Source	Bulk Density %Variance	Bulk Density Pr > F	Percent Carbon %Variance	Percent Carbon Pr > F	Total Carbon %Variance	Total Carbon Pr > F
0 - 5 cm	PLOTS	70.81%	<.0001	72.20%	<.0001	77.84%	<.0001
	SUBPLOTS	22.38%	<.0001	21.78%	<.0001	17.48%	<.0001
	WITHIN SUBPLOTS	6.82%	0.3174	6.02%	0.5175	4.68%	0.405
5 -10 cm	PLOTS	65.34%	<.0001	62.69%	<.0001	69.95%	<.0001
	SUBPLOTS	25.13%	<.0001	35.04%	<.0001	27.46%	<.0001
	WITHIN SUBPLOTS	9.53%	0.1218	2.26%	0.6289	2.59%	0.6128
10-20 cm	PLOTS	63.41%	<.0001	69.45%	<.0001	71.36%	<.0001
	SUBPLOTS	34.58%	<.0001	25.13%	<.0001	20.52%	<.0001
	WITHIN SUBPLOTS	2.01%	0.9096	5.42%	0.2524	8.11%	0.1925

Table 1

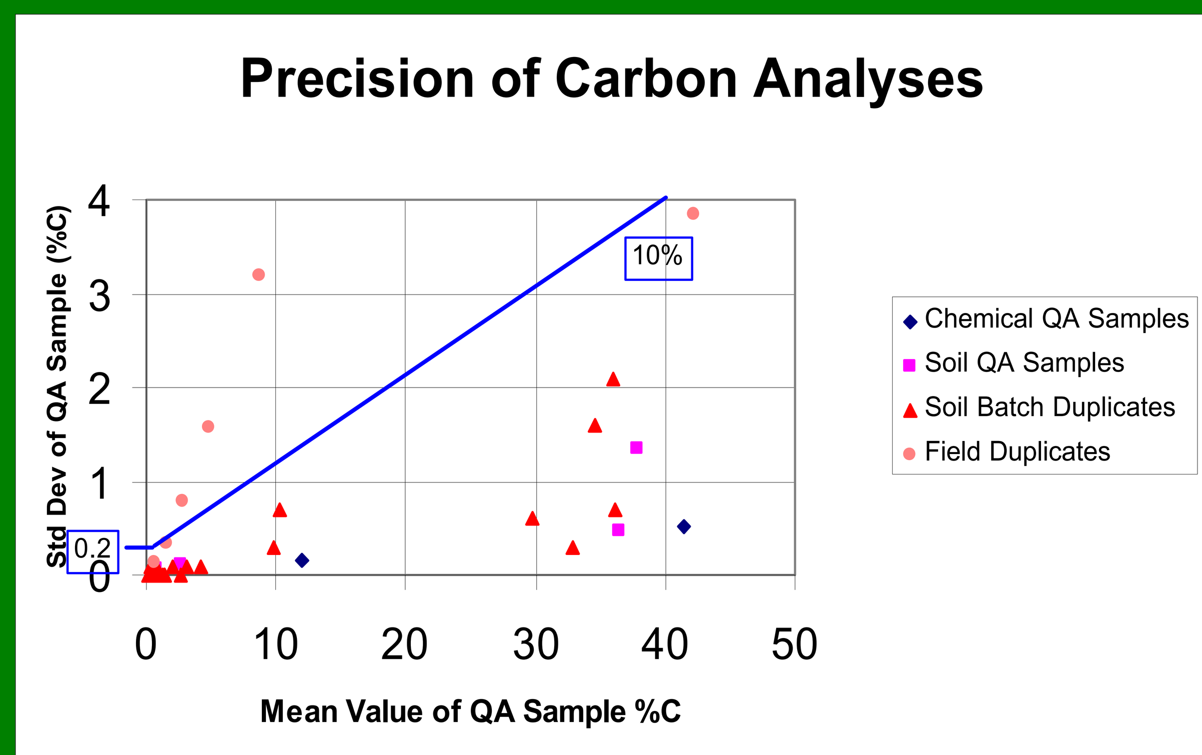

Figure 3

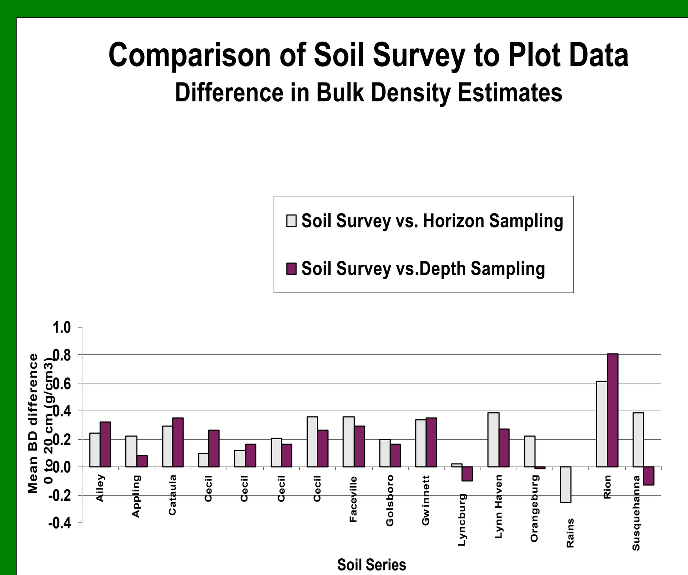

Figure 4

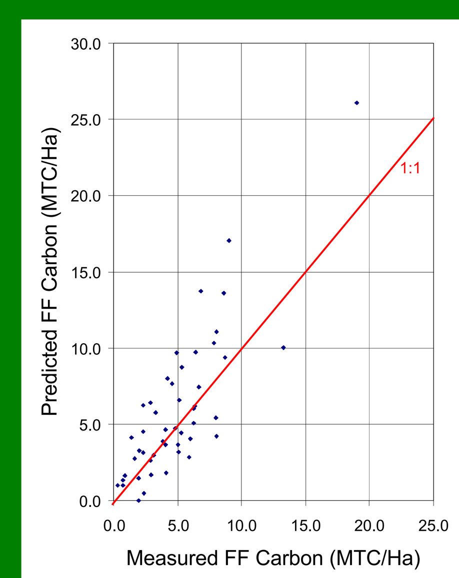

Figure 5

Return to FHM Posters Home Page

MATERIALS AND METHODS

Testing of the proposed method for sampling soil carbon content was conducted at thirty FHM plots across the state of Georgia. These plots had been sampled by soil scientists using traditional soil horizon sampling techniques during pilot studies conducted in 1991 through 1993. Predominant forest types on these plots are loblolly pine or shortleaf pine.

Five research questions were identified for specific study in this project.
How do results from the proposed sampling by depth method compare to those obtained when
sampling by soil horizons?
What is the relative variability within sampling sites, between sampling sites on a plot and between plots across a region?
What is the overall measurement error and sources of measurement variability?
Can published soil survey information be used to reduce data collection requirements?
Can sampling costs for forest floors be reduced by the collection of a few additional field measurements?

RESULTS

Comparison of Soil Sampling Methods - The soil carbon content from an example plot (Hexagon #3108442) demonstrates the large decrease in soil carbon content below the top 5 cm (Figure 2). The amount of soil carbon estimated from sampling by soil horizon is lower than that obtained by sampling by depth in the top 0-5 cm. This can be explained by the fact that the soil sample obtained for the A horizon is an average of its entire depth (0-12 cm) rather than just the top 5 cm near the surface.

Soil Variability Study - For all three parameters (bulk density, percent carbon, and total carbon) the majority of spatial variability (63% - 78%) occurs between plots and is highly significant(See Table 1). The spatial variability between subplots at individual plots ranged 17 % to 35 % of the overall variability and was also highly significant suggesting that individual subplots differ from one another in soil properties within FHM plots. The variability found at individual sampling sites ranged from 2 % to 9 % of the overall variability. This level of variability was not statistically significant, suggesting that these soils are relatively uniform at small spatial scales.

Measurement System Precision - The evaluation of the precision of soil carbon analyses is presented in Fig. 3. The detection limit was 0.2% carbon. A quality control of 10 percent relative standard deviation is used for the evaluation of quality control samples. All quality assurance samples can be measured at a level with the exception of field duplicates. Field duplicates have approximately 20 to 30 percent variability at low levels of soil carbon and about 10 percent variability at higher levels of carbon content.

An Evaluation of the Utility of Published Soil Survey Information - A comparison of the average difference in bulk densities to a depth of 20 cm is presented in Fig. 4. In this figure, bulk densities obtained by the field crews when sampling by horizon or sampling by depth is compared to that obtained from the National Soil Characterization Data website for each soil series. Soil survey information with bulk density data is not readily available for all soil series (we were able to obtain data for only 16 of the 30 plots.) Soil survey information almost always gave an overestimate of the average bulk density of the top 20 cm of soil as these data are usually obtained from agricultural soils.

Forest Floor Sampling Requirements - A comparison of the actual forest floor carbon measured to the amount predicted using the measurement of forest floor depths is presented in Fig. 5. The predicted amount averaged slightly higher (1.0 Mg C/ha) than the true amount. The variability in results was also high (relative standard deviation of 55 percent). The conclusion of this comparison is that measuring forest floor depths rather than sampling them does not provide a reliable method for estimating forest floor carbon.

CONCLUSIONS

A soil sampling procedure using a 5 cm diameter by 20 cm length core was field tested in a soil carbon study across the state of Georgia. Based on this study and subsequent field testing at a national level, we recommend the implementation of sampling by depth with a bulk density core sampler for the monitoring of near surface changes in forest soil organic matter. To provide reliable estimates of forest floor carbon, samples will need to be taken at all three soil sampling sites on the plot rather than just one.